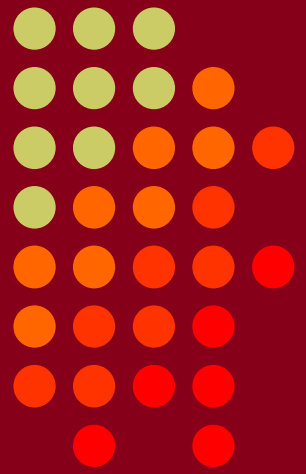
CTU Presents

Grounding and Bonding for Contest Stations

Ward Silver, NØAX



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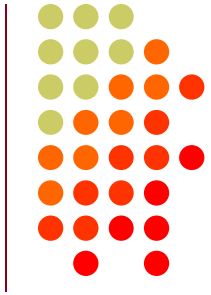
Goals of the Session



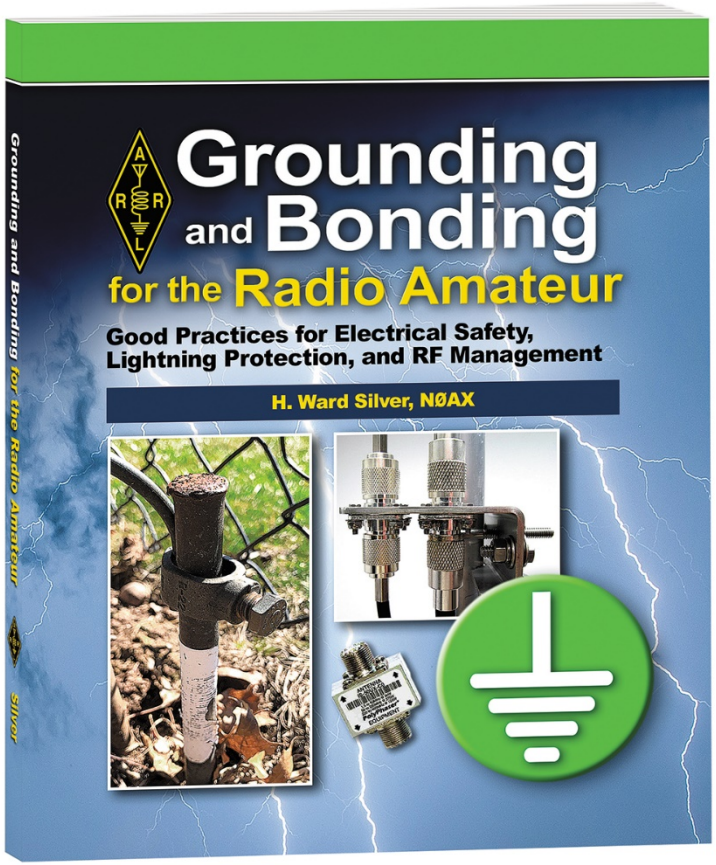
- Understand “ground” and “bond”
- Appreciate the different requirements for ac safety, lightning protection, RF and audio
- Discuss issues and techniques for contest stations
- Illustrate the system approach
- Provide comprehensive resources

Background References

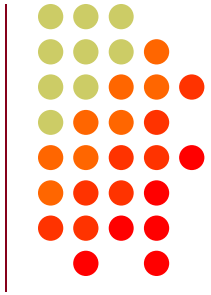
- *ARRL Handbook, ARRL Antenna Book*
- *NEC Handbook* – at your library
- *Standards and Guidelines for Communication Sites* (Motorola R56) – available online
- *Lightning Protection for the Amateur Station* (Ron Block, NR2B – Jun/Jul/Aug 2002 QST) – ARRL website
- *Power, Grounding, Bonding, and Audio for Amateur Radio* and *RFI, Ferrites, and Common Mode Chokes For Hams* – available at **k9yc.com/publish.htm**

Background References

- *Grounding and Bonding for the Radio Amateur*
  - *Covers AC wiring, lightning protection, and RF management*
  - *Reviewed by a number of experts, including the ARRL Lab*
  - *Numerous examples for you to use*

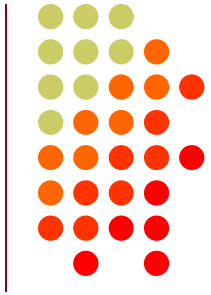


What *IS* "Ground" Anyway



- "Ground" has different meanings
  - Noun - an "earth connection" (ac, lightning) or a local reference potential (circuits, RF)
  - Verb - an action "to connect to the reference potential"
  - Adjective - a type of connection, such as a "ground conductor" or "ground system"
- It can mean *all of these things at the same time*
  - *"I'm grounding the chassis to ground with a ground wire."*

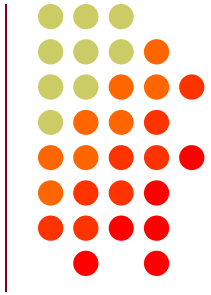
What *IS* "Ground" Anyway



- The Earth is NOT – a magic sink into which we can pour RF or lightning and expect it to magically and safely disappear

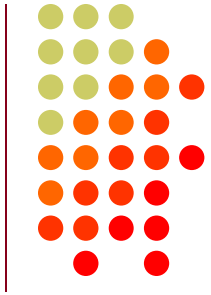
- Fuzzy definitions:
  - "RF ground" – ain't no such thing at all frequencies
  - "Ground loop" – ***hundreds*** of loops in a station
  - "Single-point ground" – it depends…

What *IS* "Ground" Anyway



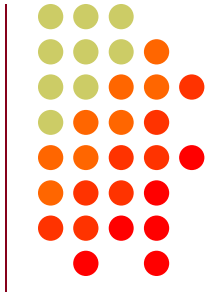
- What is a "single-point" ground?
  - Single => Electrically small in terms of wavelength
    - Small => much less than 0.1 of a wavelength
      - 60 Hz wavelength is 5 million meters
  - For ac power and audio, wavelength is long
    - Routes neutral & ground currents through correct path
    - Limits voltage from magnetic fields picked up by loops
      - Voltage is proportional to loop area
  - At RF (short wavelength) minimizes voltage differences from transmission line effects

What *IS* “Bonding” Anyway



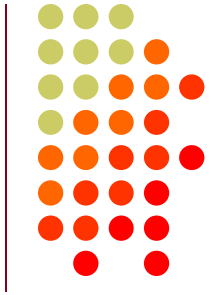
- A connection intended to keep two points at the same voltage
  - Everything goes up and down **TOGETHER**
  - Prevents shock hazards from voltage differences
  - Prevents destructive voltage differences caused by lightning surges
  - Limit current between devices caused by voltage differences from RF pickup

What *IS* “Bonding” Anyway



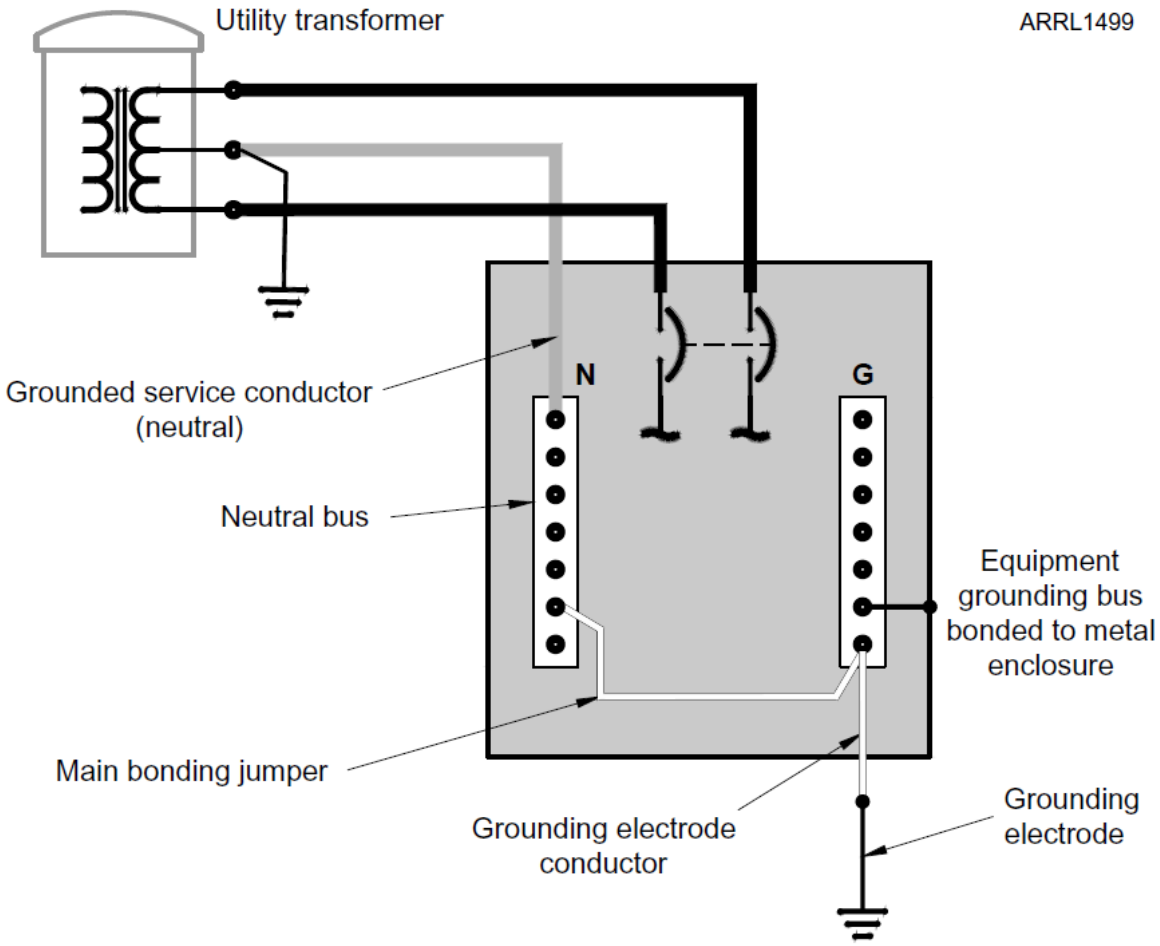
- Sounds expensive but it’s not
- Sounds hard but it’s not
- Requires the right connecting materials and hardware
- Works in your favor for ac safety, lightning protection, and RF management

What *IS* "Bonding" Anyway

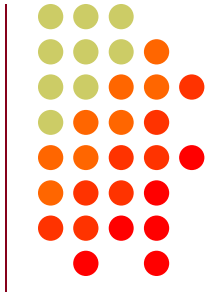


- For bonding to work, it has to be…
  - Low-Z and "short" at the frequencies of interest
  - Heavy enough to carry the expected current
  - Sturdy enough to survive the environment
- Inside the ham station, use…
  - Strap (20 ga) or heavy wire (#14 or larger)
  - Flat-weave braid if equipment moves around
    - Exposed braid from old coax deteriorates

AC Safety Grounding



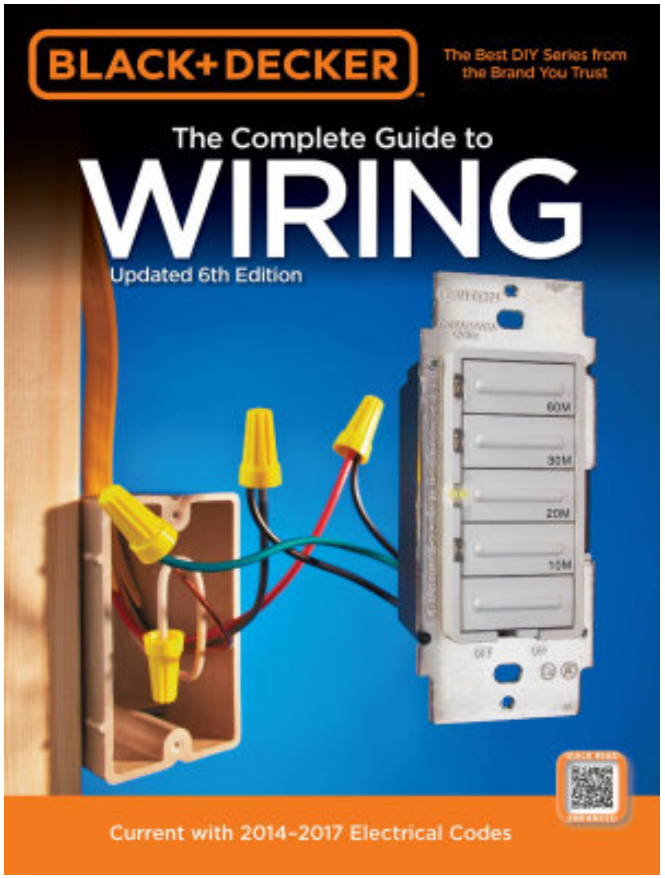
AC Safety Grounding



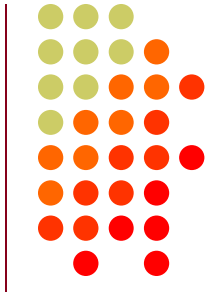
- Grounding for ac safety has several names
  - “Equipment ground”, “third-wire ground”, “green-wire ground”
- Keep ground connections low-resistance
- Purpose is two-fold
  - Provides a path to ac common point for fault current (shorts, leakage)
  - Stabilizes the ac power voltage during faults or transients, such as lightning

AC Safety Grounding

- If you aren't sure you know what you're doing…get a how-to reference
- Follow rules for sub-panels and outbuildings
- Hire a pro electrician to do the work or inspect yours
- Local code is the law

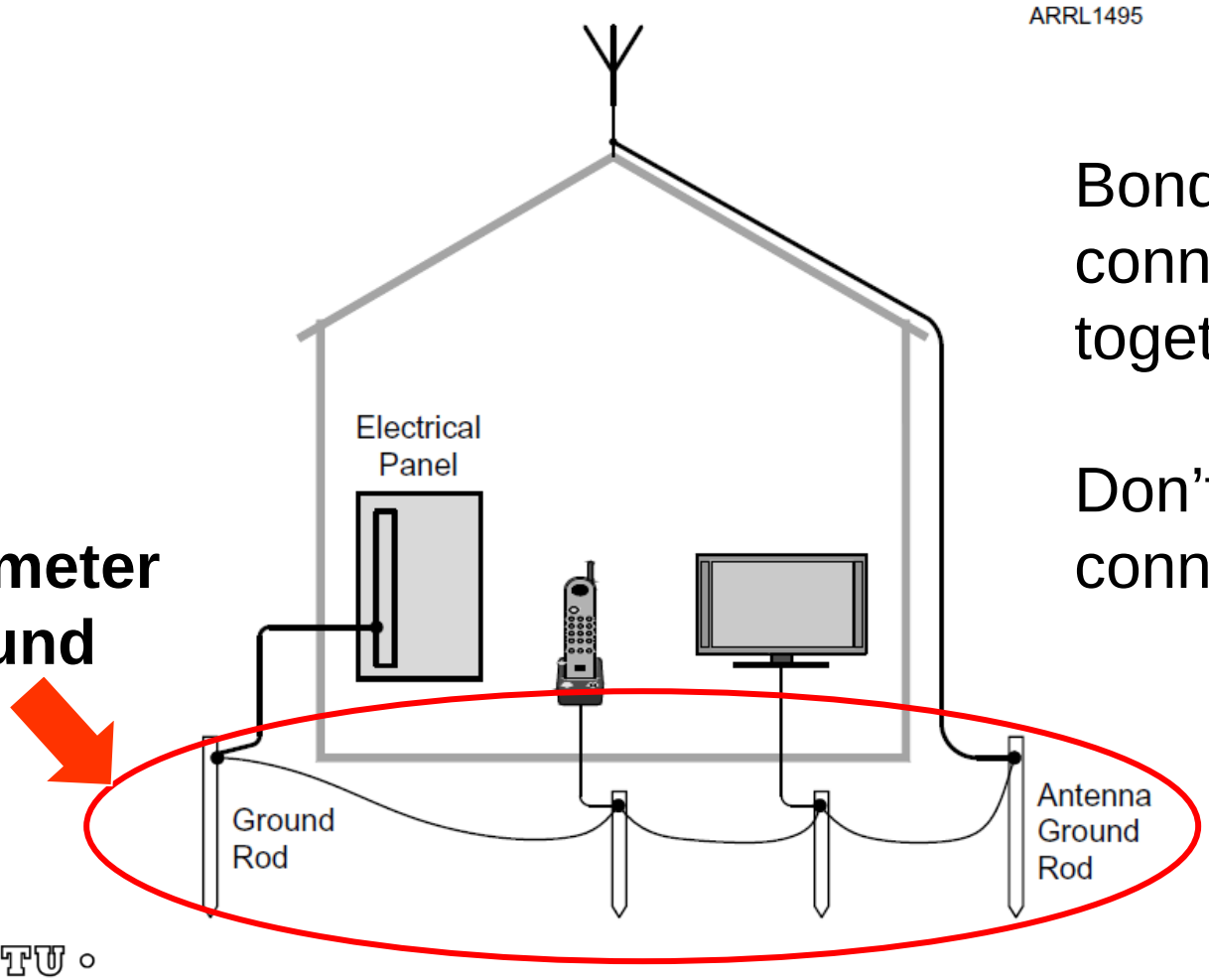


Lightning Protection



- You can't steer lightning, but…you *can* help lightning make "good decisions"
  - Heavy, low-impedance paths to the Earth
  - Paths should be *outside* your residence
  - Don't make it easy for lightning to go through your station on its way to the Earth
  - Inductance is **more important** than resistance
    - Voltage = Inductance x rate of current change
    - #12 wire has inductance of 343 nH / ft

Lightning Protection



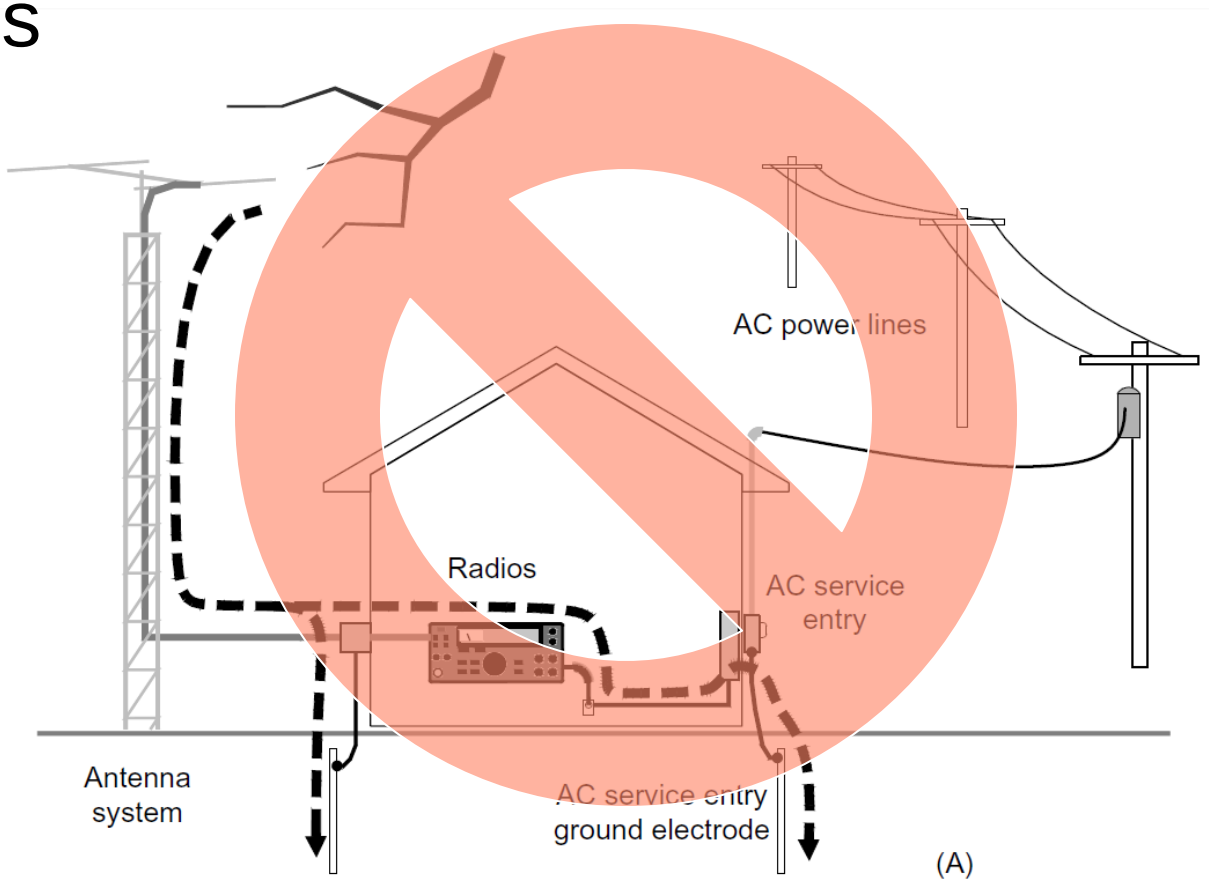
Perimeter Ground

Bond ALL earth connections together

Don't rely on dirt connections!

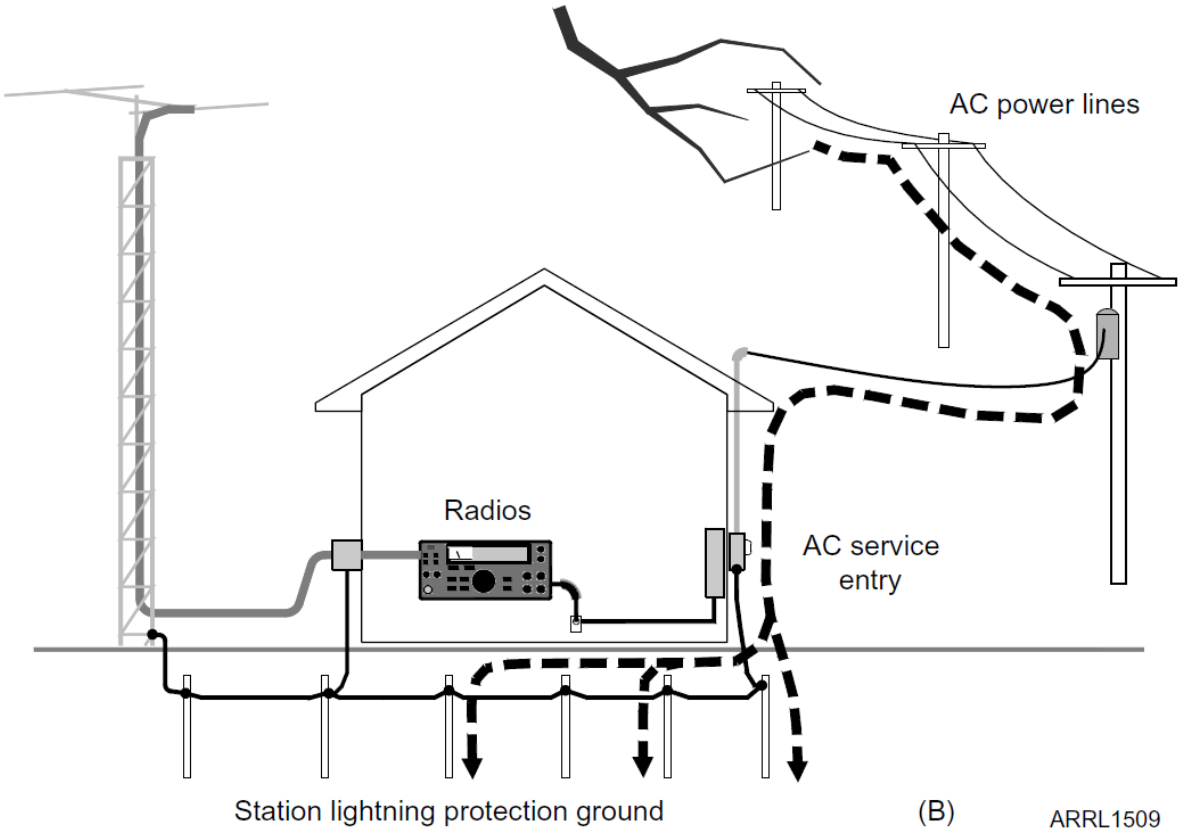
Lightning Protection

- Ground paths should go *around* your station



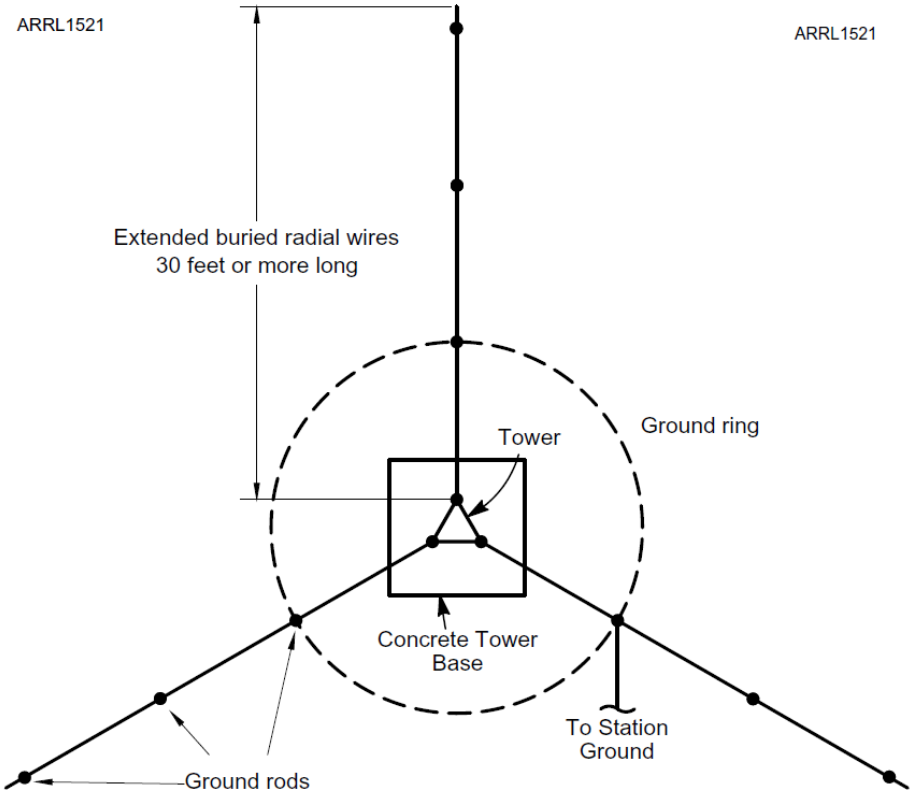
Lightning Protection

- Ground paths should go *around* your station



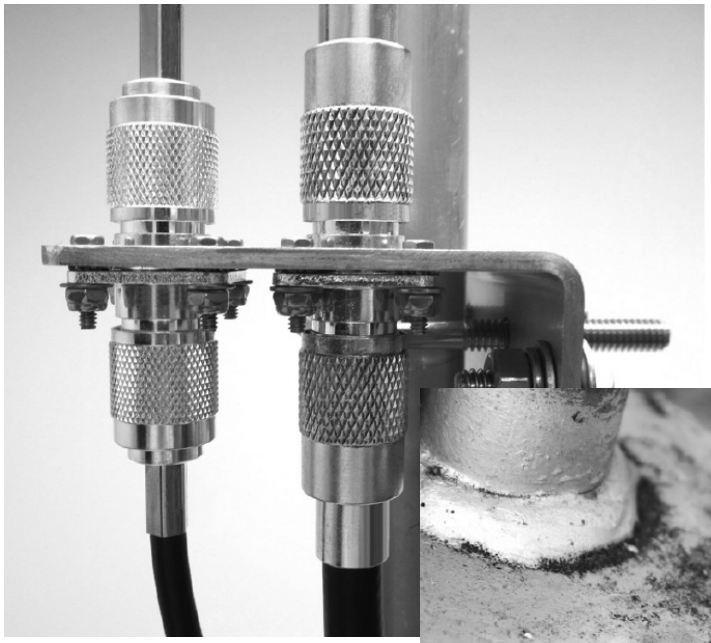
Lightning Protection

- Tower grounding



Lightning Protection

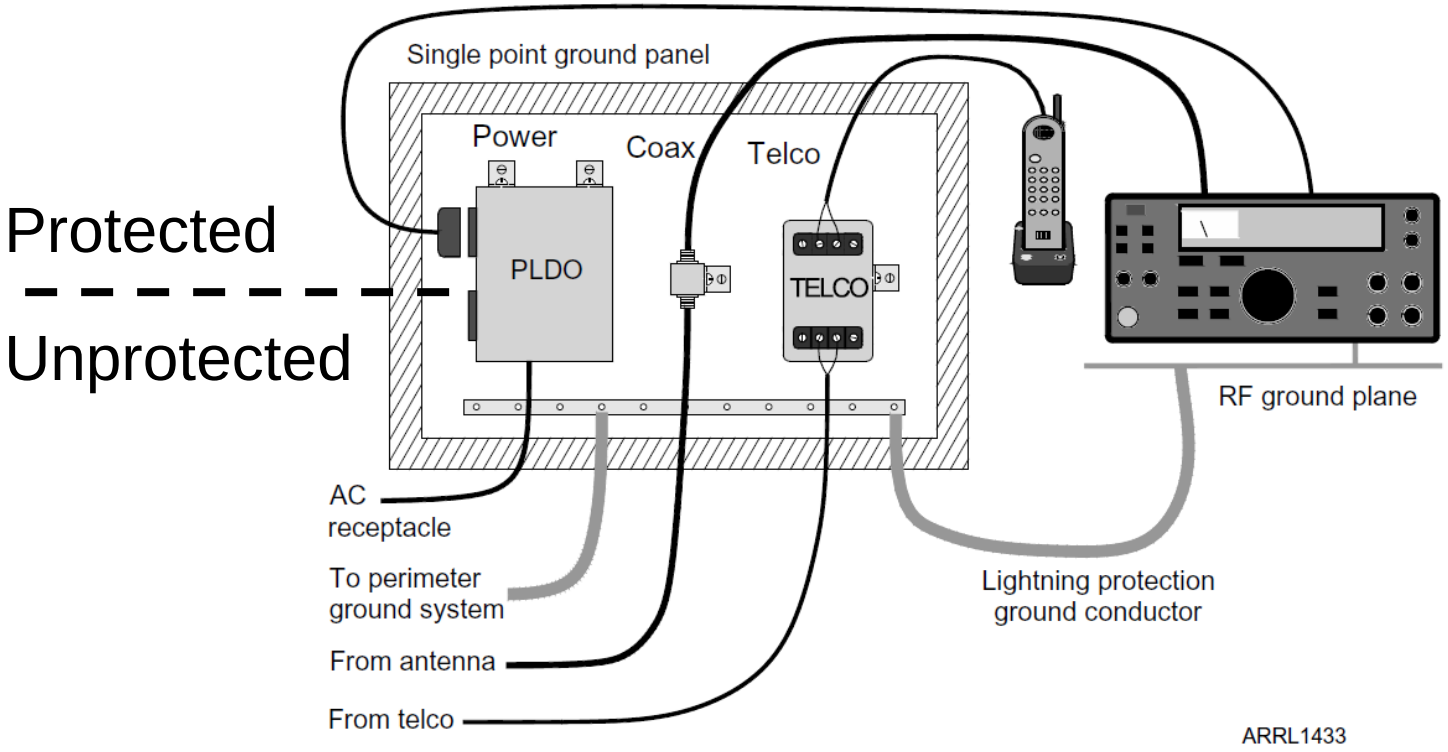
- Bond feed lines to the tower



- Spark gaps

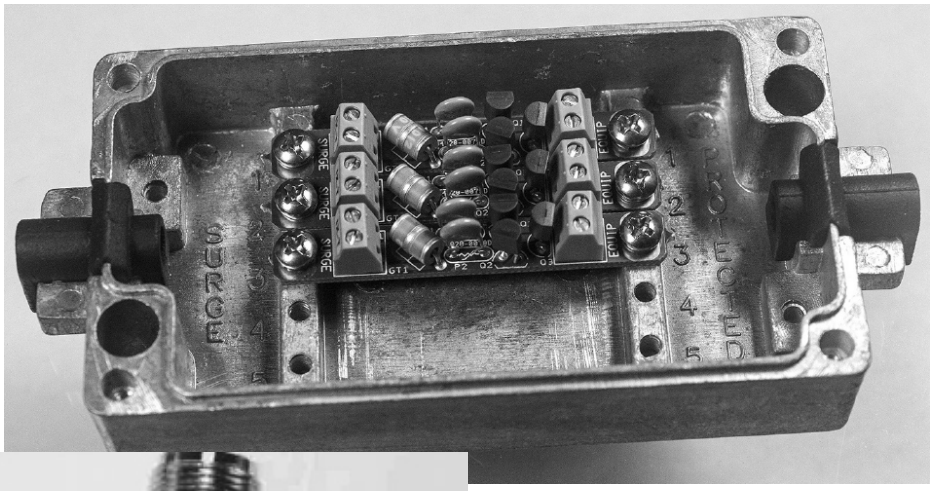
Lightning Protection

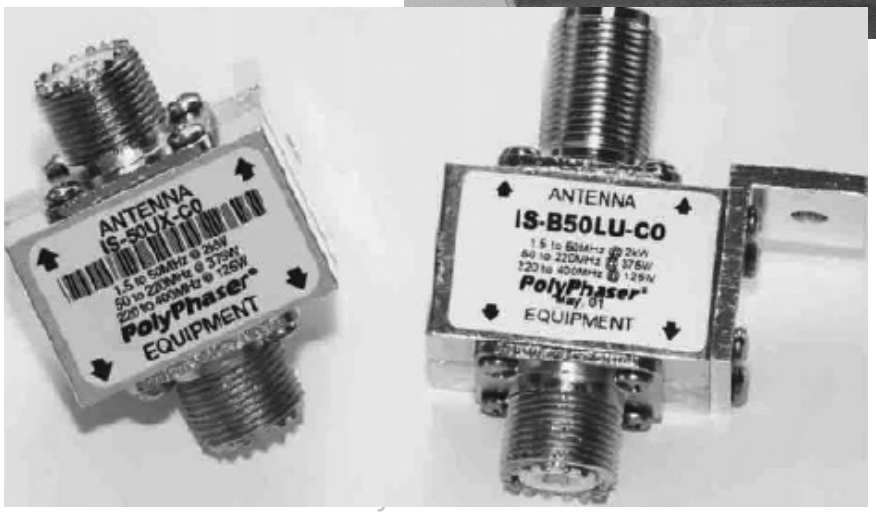
- Single-point Ground Panel



Lightning Protection

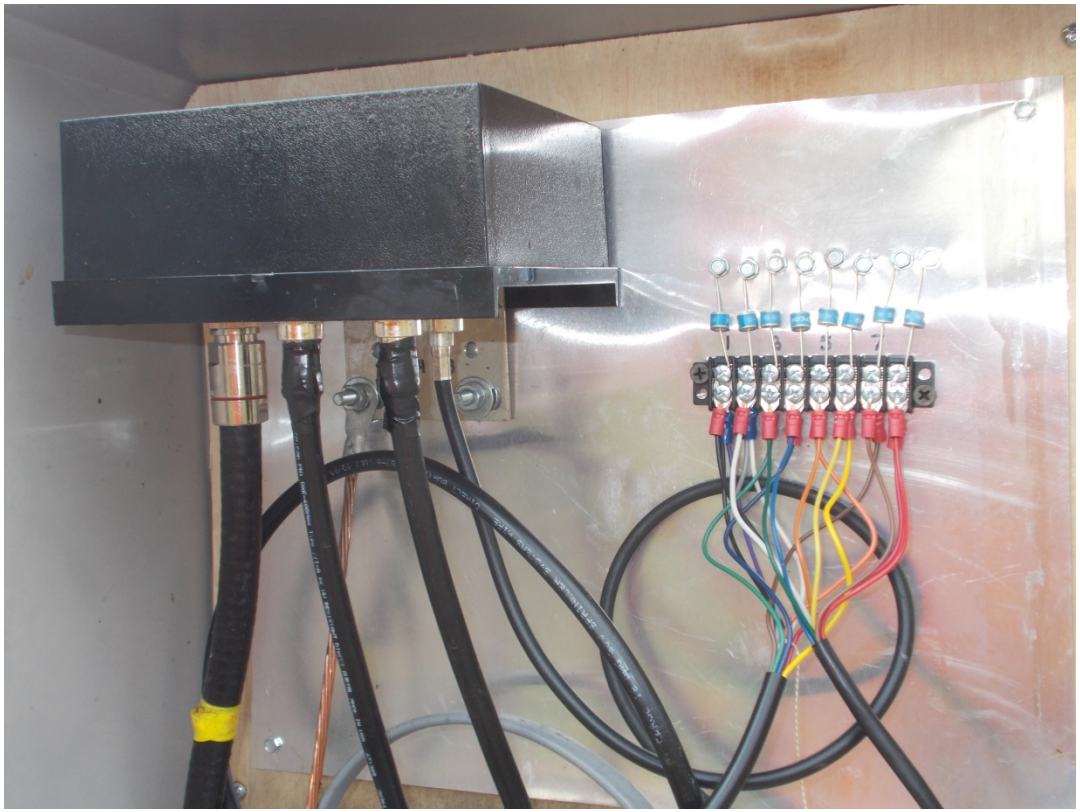
- Single-point Ground Panel





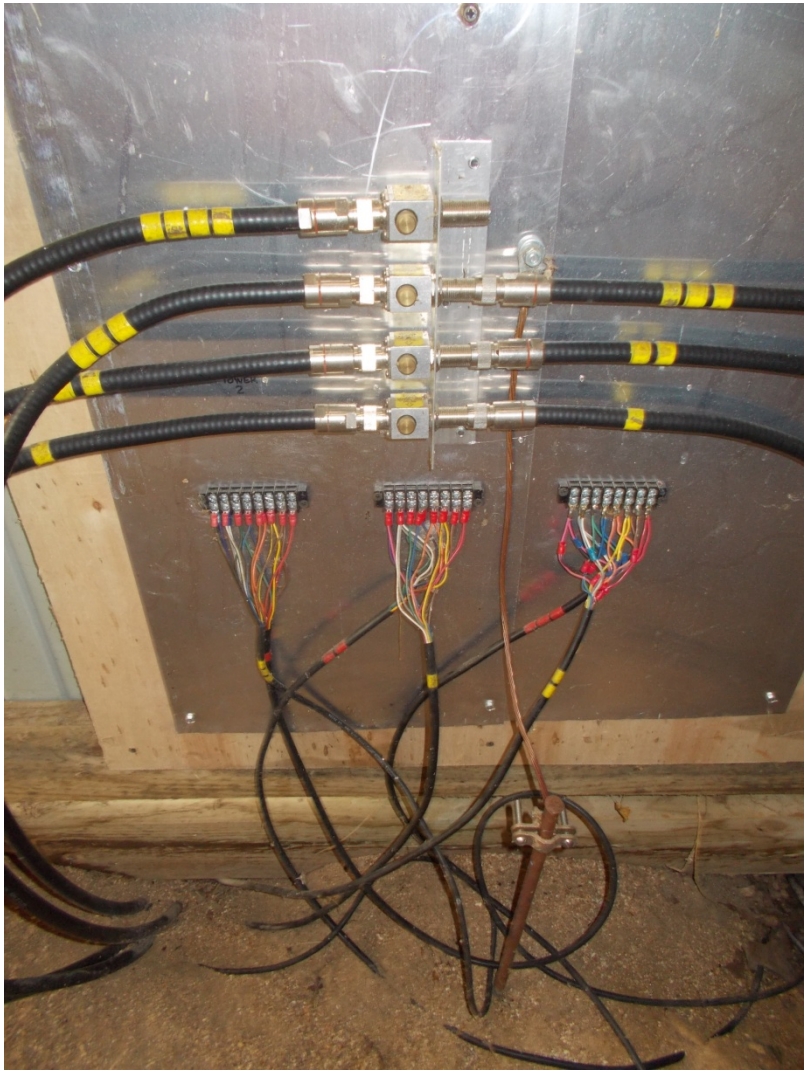
Lightning Protection

- Single-point Ground Panel



Lightning Protection

- Single-point Ground Panel

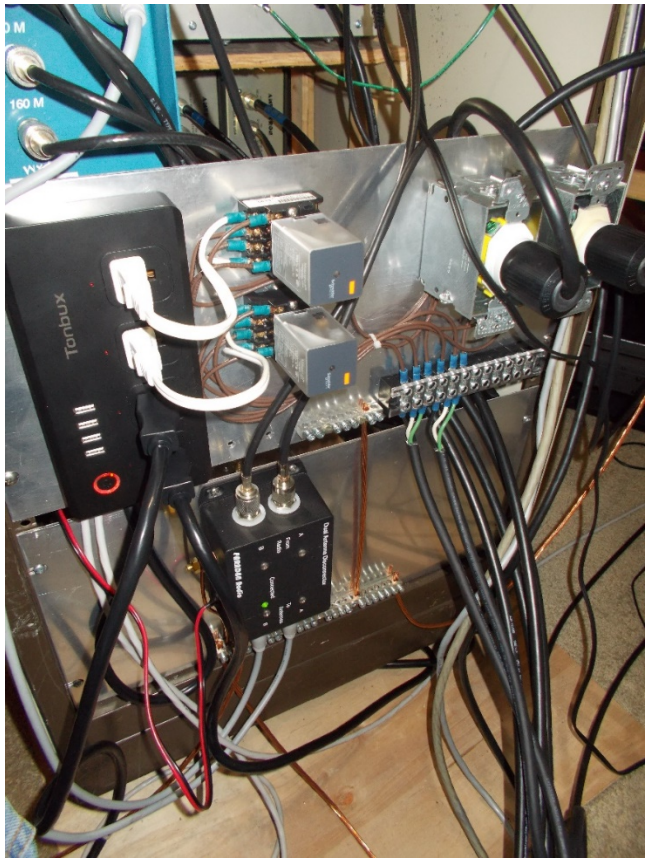


Lightning Protection

- Single-point Ground Panel

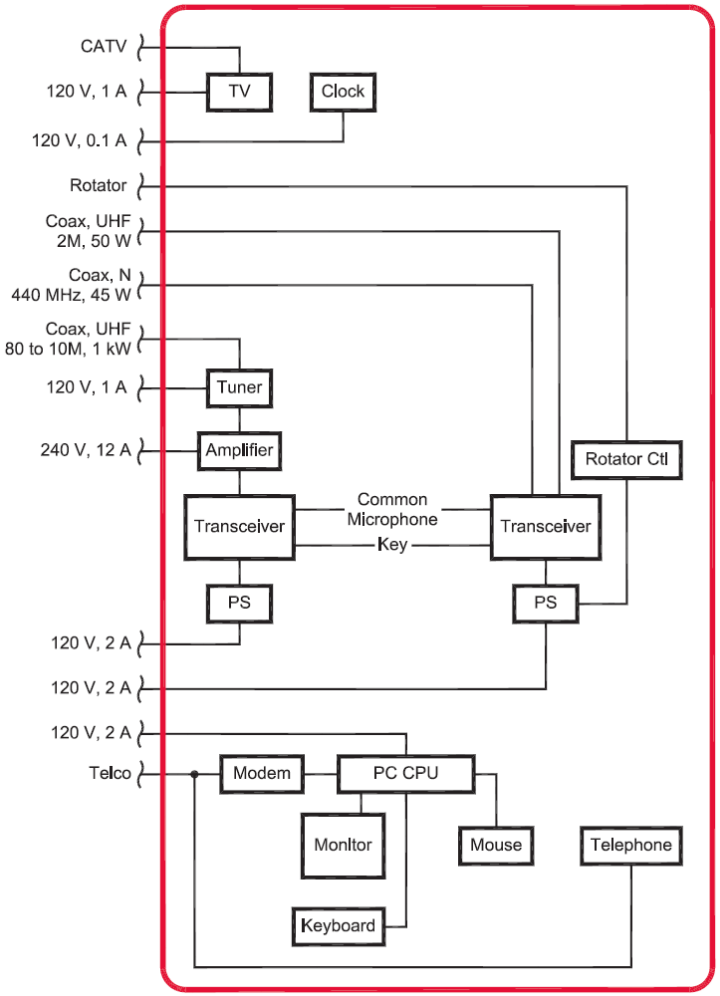
Lightning Protection

- Single-point Ground Panel (in station)



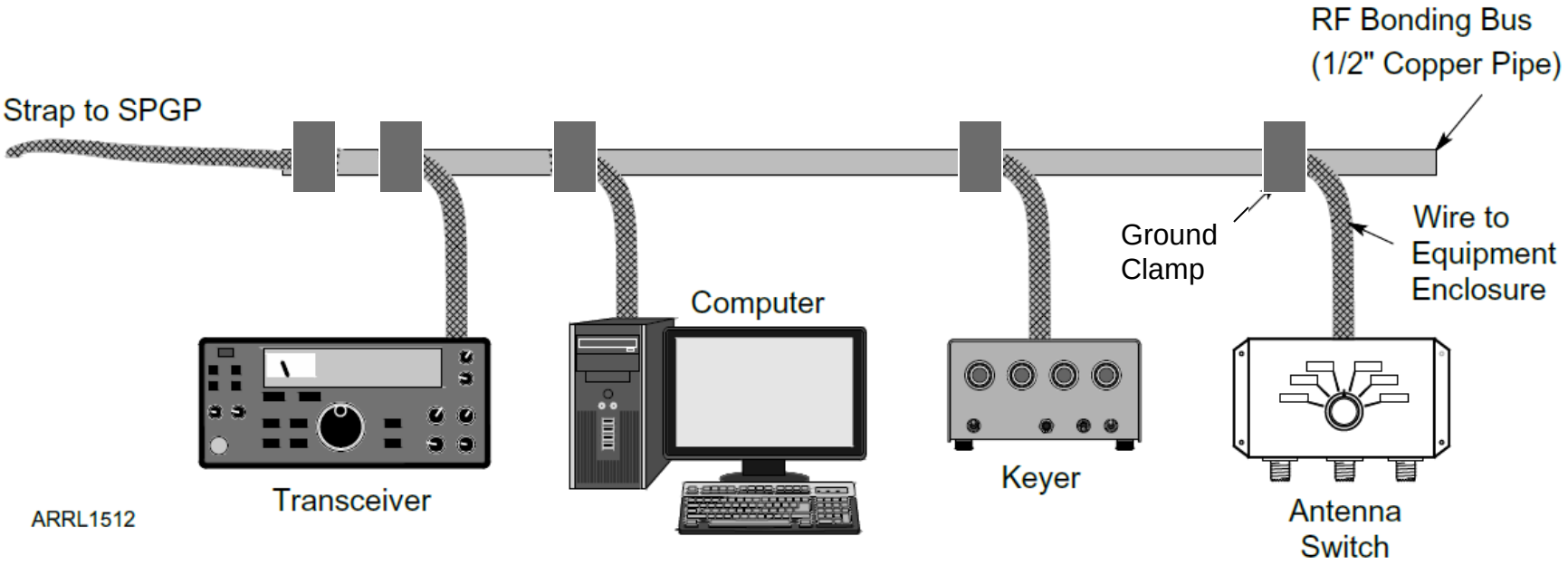
Lightning Protection

- Protected Zones
  - Every line crossing the boundary must be protected
  - Must all have a common or bonded ground connection
  - Bond equipment within the station



Lightning Protection

- Bonding inside the shack

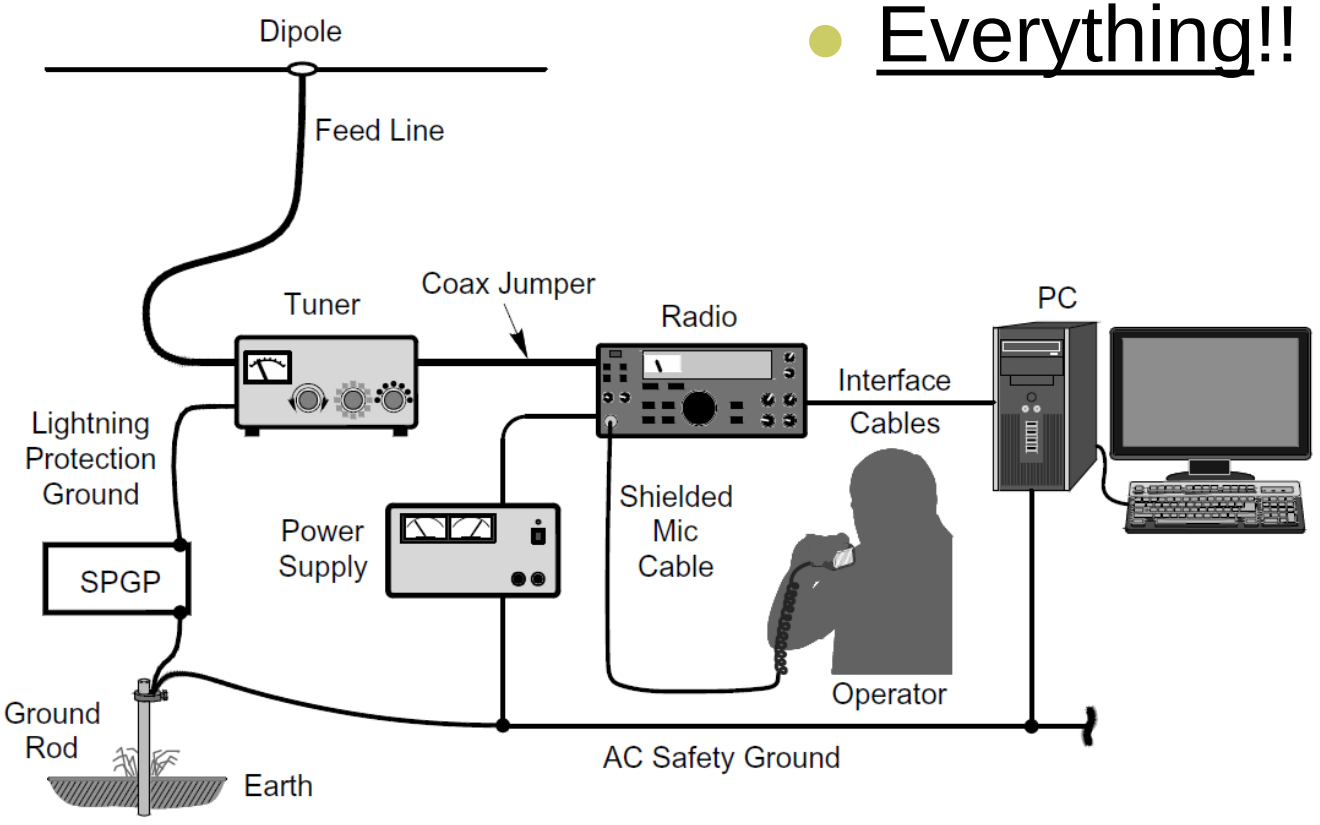


RF Management

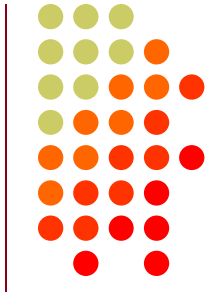
- Everything in the station is an antenna

RF Management

- Everything!!

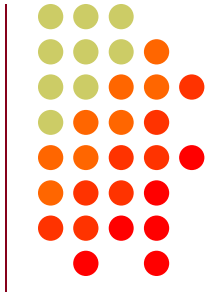


RF Management



- Everything in the station is an antenna
- Forget about an “RF ground”
  - Concentrate instead on bonding
  - Keep connections *electrically short*
  - Keep everything at the SAME voltage
- Contest stations = high RF field strength
  - Requires extra attention to bonding
- Create common reference plane and/or bus

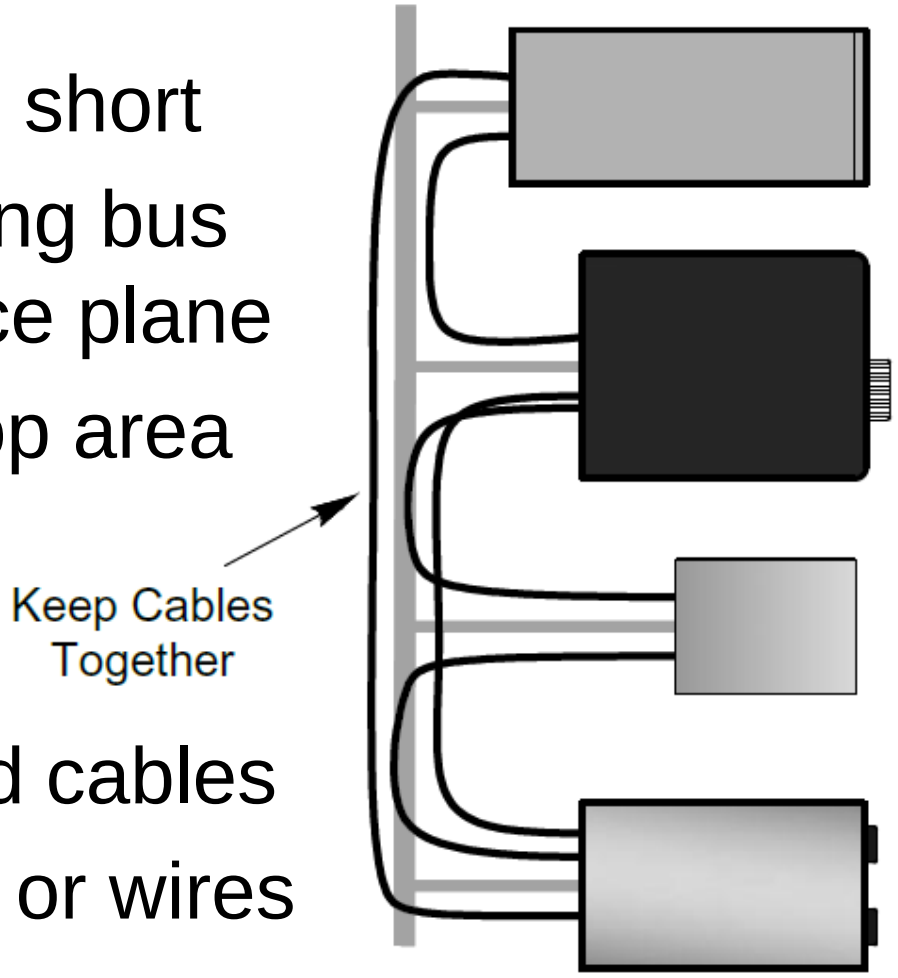
RF Management



- Equalize voltage to minimize current
  - Eliminates “hot spots”
  - Reduces RFI from common-mode current
  - Reduces sensitivity to physical configuration
  - Minimizes audio “buzz” and hum
- Tie everything to a common plane or bus
- Keep cables short or coiled
- Heavy, direct connection to SPGP

RF Management

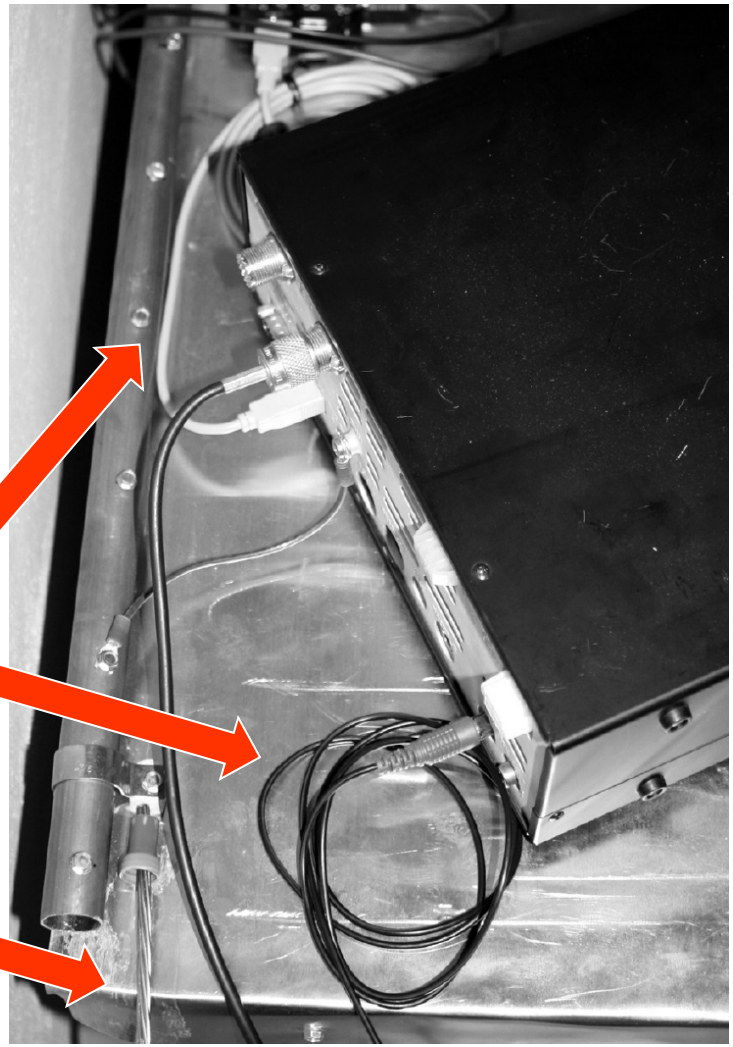
- Keep cables short
- Use a bonding bus and reference plane
- Minimize loop area



- Use shielded cables
- Short straps or wires

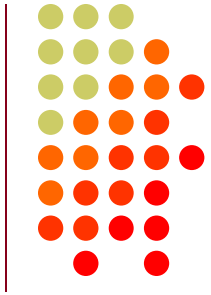
RF Management

- RF ground plane
- Sheet of metal
- Helps equalize voltage
- Run cables along the ground plane
- Bond to station ground system



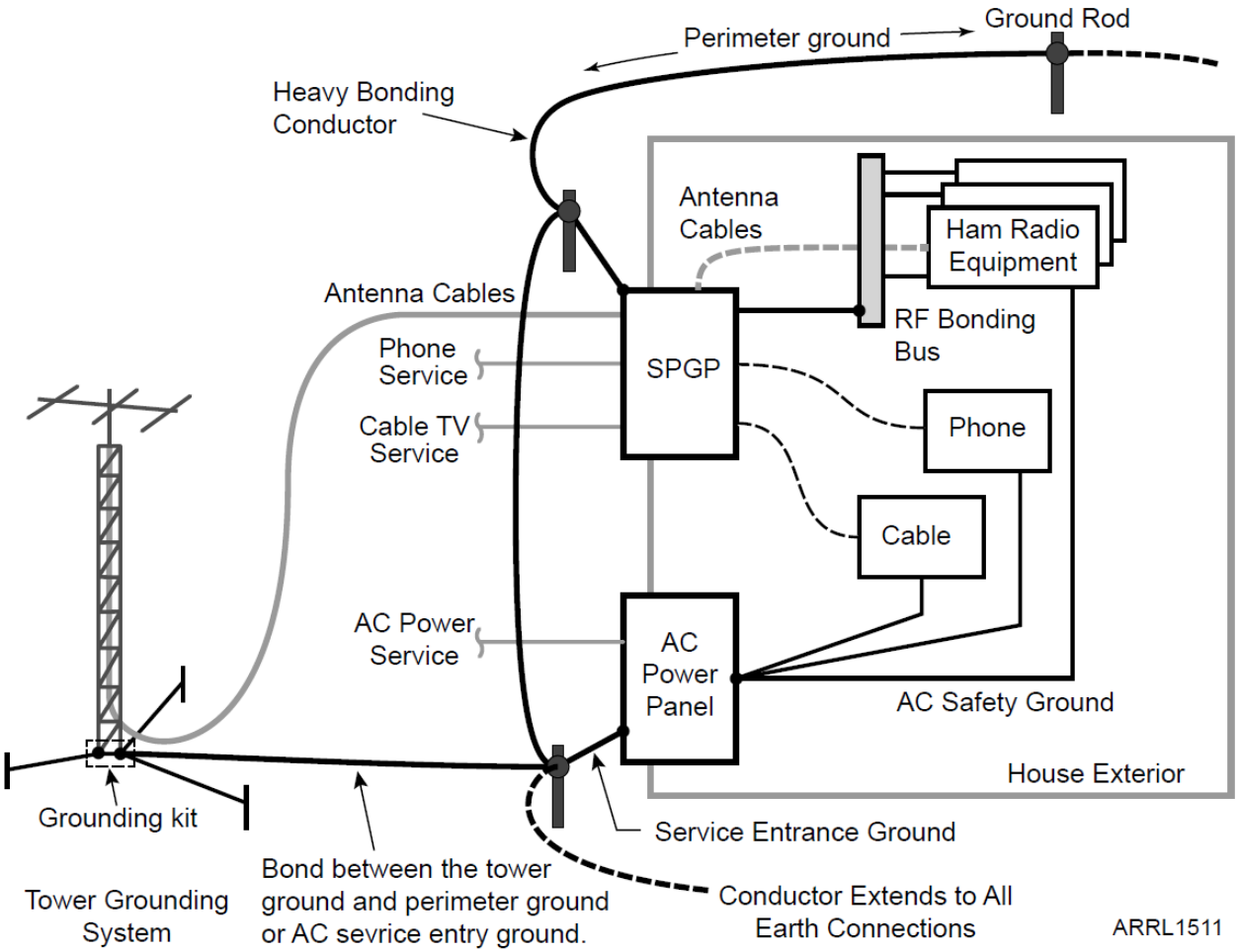
RF Management

Ground System

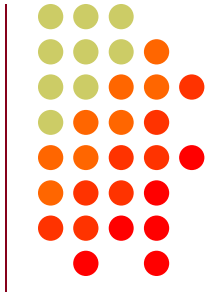


- “One system to rule them all”
- All currents flow on all wires
- A single, solid ground system made of short, heavy, direct connections satisfies all of the requirements for…
  - AC Safety
  - Lightning Protection
  - RF Management & Clean Audio

Ground System

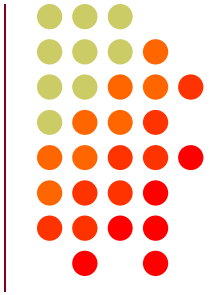


Additional Resources



- Professional Associations and Companies
  - National Fire Protection Association (**www.nfpa.org**)
  - International Association of Electrical Inspectors (**www.iaei.org**)
  - Mike Holt Enterprises (**www.mikeholt.com**) — training and continuing education for electricians, many tutorials
  - Polyphaser (**www.polyphaser.com/services/media-library/white-papers**) — various papers and tutorials on lightning protection for communications facilities, including ham stations
  - Lightning Protection Institute (**lightning.org/learn-more/library-of-resources**) — papers and tutorials on lightning protection techniques

Additional Resources

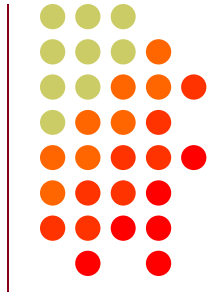


- Standards
  - FAA Document on Practices and Procedures for Lightning Protection, Grounding, Bonding, and Shielding Implementation — **www.faa.gov/documentLibrary/media/Order/6950.19A.pdf**
  - IEEE Std 1100 – 2006 “IEEE Recommended Practices for Powering and Grounding Electronic Equipment” — **www.ieee.org** (available from most libraries)
  - MIL-HDBK-419A – Grounding, Bonding, and Shielding for Electronic Equipments and Facilities (Vol 1 and 2) — **www.uscg.mil/petaluma/TPF/ET/_SMS/Mil-STDs/MILHDBK419.pdf**

Additional Resources

- Books and Online Material
  - Block, R. R., The “Grounds” for Lightning and EMP Protection, Second Edition, PolyPhaser Corporation, 1993.
  - Rand, K. A., Lightning Protection and Grounding Solutions for Communications Sites, PolyPhaser Corporation, 2000.
  - ARRL Technical Information Service sections
    - Electrical Safety — **www.arrl.org/electrical-safety**
    - Grounding (various types and topics) — **www.arrl.org/grounding**
    - Lightning Protection - **www.arrl.org/lightning-protection**
  - W8JI’s web pages on ground systems (**w8ji.com/ground_systems.htm**)

ARE WE DONE YET?



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